Wheatstone Bridge

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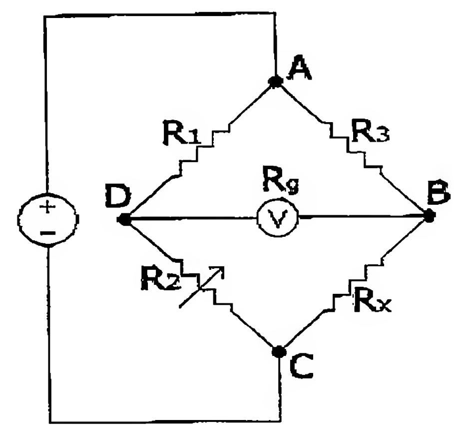
A **Wheatstone bridge** is a measuring instrument invented by Samuel Hunter Christie in 1833 and improved and popularized by Sir Charles Wheatstone in 1843. It is used to measure an unknown electrical resistance by balancing two legs of a bridge circuit, one leg of which includes the unknown component. Its operation is similar to the *original* potentiometer except that in potentiometer circuits the meter used is a sensitive galvanometer.



Wheatstone's bridge circuit diagram.

In the circuit at right, R_x is the unknown resistance to be measured; R_1, R_2 and R_3 are resistors of known resistance and the resistance of R_2 is adjustable. If the ratio of the two resistances in the known leg (R_2 / R_1) is equal to the ratio of the two in the unknown leg (R_x / R_3), then the voltage between the two midpoints will be zero and no current will flow between the midpoints. R_2 is varied until this condition is reached. The current direction indicates if R_2 is too high or too low.

Detecting zero current can be done to extremely high accuracy (see Galvanometer). Therefore, if R_1, R_2 and R_3 are known to high precision, then R_x can be measured to high precision. Very small changes in R_x disrupt the balance and are readily detected.

If the bridge is balanced, which means that the current through the galvanometer R_g is equal to zero, the equivalent resistance of the circuit between the source voltage terminals is:

$R_1 + R_2$ in parallel with $R_3 + R_x$

$$R_E = \frac{(R_1 + R_2) \cdot (R_3 + R_x)}{R_1 + R_2 + R_3 + R_x}$$

Alternately, at this point of balance, the ratio of $R_2 / R_1 = R_x / R_3$

Therefore, $R_x = (R_2 / R_1) * R_3$

Alternatively, if R_1, R_2, and R_3 are known, but R_2 is not adjustable, the voltage or current flow through the meter can be used to calculate the value of R_x, using Kirchhoff's circuit laws (also known as Kirchhoff's rules). This setup is frequently used in strain gauge and Resistance Temperature Detector measurements, as it is usually faster to read a voltage level off a meter than to adjust a resistance to zero the voltage.

Contents

Derivation

First, we can use the first Kirchhoff rule to find the currents in junctions **B** and **D**:

$$\begin{aligned} I_3 - I_x - I_g &= 0 \\ I_1 - I_g - I_2 &= 0 \end{aligned}$$

Then, we use Kirchhoff's second rule for finding the voltage in the loops **ABD** and **BCD**:

$$\begin{aligned} I_3 \cdot R_3 + I_g \cdot R_g - I_1 \cdot R_1 &= 0 \\ I_x \cdot R_x - I_2 \cdot R_2 - I_g \cdot R_g &= 0 \end{aligned}$$

The bridge is balanced and $I_g = 0$, so we can rewrite the second set of equations:

$$\begin{aligned} I_3 \cdot R_3 &= I_1 \cdot R_1 \\ I_x \cdot R_x &= I_2 \cdot R_2 \end{aligned}$$

Then, we divide the equations and rearrange them, giving:

$$R_x = \frac{R_2 \cdot I_2 \cdot I_3 \cdot R_3}{R_1 \cdot I_1 \cdot I_x}$$

From the first rule, we know that $I_3 = I_x$ and $I_1 = I_2$. The desired value of R_x is now known to be given as:

$$R_x = \frac{R_3 \cdot R_2}{R_1}$$

If all four resistor values and the supply voltage (V_s) are known, the voltage across the bridge (V) can be found by working out the voltage from each potential divider and subtracting one from the other. The equation for this is:

$$V = \frac{R_x}{R_3 + R_x} V_s - \frac{R_2}{R_1 + R_2} V_s$$

This can be simplified to:

$$V = \left(\frac{R_x}{R_3 + R_x} - \frac{R_2}{R_1 + R_2} \right) V_s$$

The Wheatstone bridge illustrates the concept of a difference measurement, which can be extremely accurate. Variations on the Wheatstone bridge can be used to measure capacitance, inductance, impedance and other quantities, such as the amount of combustible gases in a sample, with an explosimeter. The **Kelvin Double bridge** was one specially adapted for measuring very low resistances. This was invented in 1861 by William Thomson, Lord Kelvin.

The concept was extended to alternating current measurements by James Clerk Maxwell in 1865 and further improved by Alan Blumlein in about 1926.

Modification of the fundamental bridge

Wheatstone bridge is the fundamental bridge. But there are other modifications. These modifications are

made to measure various kind of resistances. Fundamental one is not always suitable. Some of the modifications are:

- Karey-Foster Slide-wire bridge
- Kelvin Varley Slide
- Kelvin Double bridge

See also

- Strain gauge
- Potentiometer
- Potential divider
- Ohmmeter
- Resistance Temperature Detector
- Maxwell bridge
- E-meter

Electronics Portal

External links

- efunda Wheatstone article (http://www.efunda.com/designstandards/sensors/methods/wheatstone_bridge.cfm)
- a typical mV/V Bridge Simulator (http://www.interfaceforce.com/_products/documents/PrecLC_Sim_109.pdf)

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